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(54) Title: **MANUFACTURING APPARATUS AND METHOD**

(57) Abstract: The present invention provides an assembly system employing at least a robotic or automated assembly apparatus to manipulate the components to be assembled and at least a first vision alignment system to align the components prior to their assembly. An adhesive dispense system is provided to connect, attach or otherwise adhere the components together. In a method in accord with the present invention for assembling components, a source of the components is provided is located relative to a global reference system. The components held by the source are then located relative to the global reference system based upon the determined location of the source. An adhesive is dispensed onto a first of the components and a second component is manipulated into an initial attachment position relative to the first component. The components are imaged by a local imaging system to establish their position relative to each other and the second component is moved into a desired attachment position and then moved into engagement with the adhesive and the first component. The adhesive may then be at least partially cured if desired.

WO 01/71437 A2

MANUFACTURING APPARATUS AND METHOD

FIELD OF THE INVENTION

The present invention relates generally to robotic manufacturing and in particular to apparatus and method for attaching a flexible circuit to a suspension used in the read/write head gimbal assembly of hard disk drives.

BACKGROUND OF THE PRESENT INVENTION

The hard disk drive is the device most predominantly used for long term memory storage in modern computer systems. In overview, a hard disk drive comprises a disk that is rotated at high speeds. The disk has a magnetic coating and selected areas of the coating can be magnetized with the application of a magnetic field. A "read/write" device, commonly called a head, is suspended above the disk and moved radially, that is, from the edge of the disk toward the center and back. Electric current is provided to the head which creates and applies a magnetic field to the disk as the head moves. Selective areas of the disk are preferentially magnetized as the magnetic field is applied to the disk. Each magnetized area consists of a north and south pole selectively oriented in one of two preferred directions. Magnetized areas having a north pole pointing in one of the two direction are designated as a "0" and in the other direction as a "1." In this way the binary language of computers consisting of zeroes and ones is assembled and data

1 and programs, which comprise zeroes and ones in binary computer language, are
2 stored on the hard disk.

3 The hard disk provides large amounts of storage capability at relatively low
4 cost. In addition, as the technology continually matures, the storage density per unit
5 of cost, that is, the quantity of data stored per dollar, is continuously increasing, as
6 is the reliability of the hard disk and its related components, (collectively called the
7 hard disk drive, hard drive, or disk drive) and the rate at which data can be
8 transferred to and from the disk. That is, advancing hard disk technology is
9 resulting in the storage of increasing amounts of information at decreasing unit
10 costs. Yet, in spite of the rapid advance in storage technology, the technology
11 continues to face cost pressures as competition in the marketplace intensifies and
12 computer programs grow in size.

13 An exploded view of a flex circuit/suspension assembly is shown in Figure
14 6, which illustrates several components including a suspension A and a flex circuit
15 B. It will be understood that the actual physical structures of these components may
16 vary in configuration. Typically, the suspension A will include a base plate C, a
17 radius (spring region) D, a loadbeam E, and a gimbal F. At least one tooling
18 aperture G may be included. The flex circuit B may include a base H, which may
19 be a synthetic material such as a polyimide, that supports typically a plurality of
20 electrical traces or leads I of the flex circuit. In addition, any of the surface features
21 of the suspension A and the flex circuit B, such as the loadpoint J of the suspension
22 A or the cure holes K of the flex circuit B, can be designated an optical target or an
23 alignment target for use in the process of assembling the flex circuit and the
24 suspension to each other. Additionally, the suspension A and/or flex circuit B may
25 include fiducials that are specifically placed thereon for imaging purposes during
26 an assembly operation.

27 The components shown in Figure 6 as well as all those associated with hard
28 disk drives are small and continually decreasing in size. Consequently, any
29 tolerance for misalignment of the components during the assembly process is also
30 continuously decreasing while their susceptibility to damage during assembly is
31 increasing.

1 Current disk drive assembly includes expensive, labor intensive processes,
2 particularly the assembly of the flex circuit to the suspension assembly. The labor
3 intensive nature of the assembly process has several consequences. First, the labor
4 increases the final cost of the assembled suspension. Second, because of the heavy
5 use of labor in the assembly, there is a meaningful quantity of handling of the
6 components by the assembler, which increases the likelihood of damage to the
7 components. Third, the assemblers are limited in both the precision and speed with
8 which the flex circuits can be assembled to the suspensions. Fourth, even though
9 human assemblers are used, the assembly process is quite tooling intensive.
10 Finally, as the part geometries change as the technology advances, the costs also
11 increase because of the need for new tooling in the assembly of the new parts; that
12 is, the tooling used is either not adaptable or not readily adaptable to new part
13 geometries.

14 Additional costs that are not included in calculation of the cost of the use of
15 human assemblers are those of the consumer whose hard drive fails, perhaps due to
16 damage to a component by a human assembler. Though data backups are always
17 advised, such advice is often unheeded. When a hard drive fails the consumer may
18 lose valuable data that is either not easily replaced or is replaced only at some cost
19 in terms of time and effort, if not actual cash outlays.

20 Many of the foregoing deficiencies in the employment of human assemblers
21 could be reduced or eliminated with a precision automated assembly apparatus and
22 method for attaching flex circuits to suspensions. Automated assembly machines
23 and methods should result in lower costs, reduced component handling and possible
24 damage, and have greater flexibility to accommodate variations in component types,
25 geometries and improved placement tolerances.

26 SUMMARY OF THE INVENTION

27 It is an object of the present invention to provide new and improved
28 apparatus and methods that are not subject to the foregoing disadvantages.

29 It is another object of the present invention to provide an apparatus that can
30 be used for the automated assembly of one or more component parts of a read/write
31 head gimbal assembly to each other.

1 It is still another object of the present invention to provide a method for the
2 assembly of one or more component parts of a read/write head gimbal assembly to
3 each other.

4 The foregoing objects of the present invention are provided by an assembly
5 system employing at least a robotic or automated assembly apparatus to manipulate
6 the components to be assembled and at least a first vision alignment system to align
7 the components prior to their assembly. An adhesive dispense system is provided
8 to connect, attach or otherwise adhere the components together.

9 In a method in accord with the present invention, a plurality of component
10 parts are assembled to each other. A source of the component parts is provided and
11 the source is located relative to a global or absolute reference system. The
12 components held by the source are then located relative to the global reference
13 system based upon the determined location of the source. An adhesive is dispensed
14 onto a first of the components. A second component is manipulated into an initial
15 attachment position relative to the first position and the components are imaged by
16 a second or local imaging system to establish their position relative to each other.
17 The second component will be manipulated relative to the first based upon their
18 calculated relative positions to position the second component at the desired
19 attachment position and then will be lowered into engagement with the adhesive
20 and the first component. The adhesive may then be at least partially cured if
21 desired.

22 The foregoing objects of the invention will become apparent to those skilled
23 in the art when the following detailed description of the invention is read in
24 conjunction with the accompanying drawings and claims. Throughout the
25 drawings, like numerals refer to similar or identical parts.

26 BRIEF DESCRIPTION OF THE DRAWINGS

27 Figure 1 illustrates an apparatus in accord with the present invention in a
28 perspective overview.

29 Figure 2 shows the manipulator arm of Figure 1 in a front elevation view.

30 Figure 3 depicts the manipulator arm of Figure 1 in a side elevation view.

Figure 4 illustrates the light source of Figures 1-4 in a top plan view.

Figure 5 is a process flow chart of a method in accord with the present invention.

Figure 6 illustrates a flex circuit/suspension of the type that can be assembled with the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

An assembly apparatus 10 in accord with the present invention is shown in the Figures. Referring to Figure 1, apparatus 10 includes a cover 12, shown in phantom, and a cabinet 14. Cover 12 may be hingeably attached to the cabinet 14. Cabinet 14 supplies the support structure for the assembly apparatus to be described in greater detail hereafter. Cabinet 14 may include a table 16 that supports a plurality of component trays 16 and 18 at predetermined locations. Trays 16 and trays 18 hold components to be attached or otherwise connected to each other, for example, flex circuits and suspensions. Cabinet 14 also supports an xyz and θ robot 20 that is controlled by an appropriately programmed computer 22 or other appropriate device over a line 24. Robot 20 is capable of manipulating parts in an orthogonal xyz coordinate system rotationally about the z axis, thus providing manipulation in the θ angular direction.

It will be understood by those in the art that both trays 16 and 18 could be placed in any desired arrangement relative to robot 20 and that the components contained therein could also be arranged as desired within the trays. In any event computer 22 will be programmed with the necessary information as to the relative locations of the trays and the components therein.

The particular robotic system or apparatus 20 shown in the Figure is of the type presently manufactured by Zmation, Inc. of Portland, Oregon, and additional details concerning its construction and operation can be obtained from the manufacturer. Other manufacturers of similar robotic apparatus include Anorad Corporation of Hauppauge, New York.

Robot 20 is movable in a plurality of rectangular coordinate axes and in at least one angular or rotational degree of freedom, as will be described hereafter. In

1 addition, as is known in robotic assembly equipment, robot 20, could, if desired,
2 include the ability to manipulate components in additional degrees of freedom, that
3 is angularly.

4 Robot 20 includes a pair of horizontal rails 26, 28 each supported by a pair
5 of posts 30, 32, respectively. A transverse rail 34 is movable along rails 26 and 28
6 in the direction indicated by double-headed arrow 36. Thus, rail 34 is movable in
7 the X direction or along the X axis and is sometimes referred to in the art as the X
8 stage.

9 Rail 34 supports a manipulator arm 38 that is transversely movable relative
10 to the rails 26 and 28 along transverse rail 34 in the direction indicated by double
11 headed arrow 40. Thus, arm 38 is movable in the Y direction or along the Y axis
12 and is sometimes referred to in the art as the Y stage.

13 In addition, portions of the manipulator arm 38 will also be movable in the
14 direction of double headed arrow 42. This is the Z direction or Z axis. Portions of
15 the arm 38 are also movable in an angular direction as shown by double headed
16 arrow 44.

17 Collectively, it will be understood that arrows 36, 40, and 42 define a
18 rectangular or xyz axis coordinate system and that the manipulator arm portions to
19 be described hereafter are rotatable about the Z axis as noted earlier.

20 Various devices are known in the art for providing movement in a robot
21 system such as that illustrated here. For example, movement along each axis could
22 be provided by an appropriate device for providing linear motion, such as linear
23 servo motors or other linear actuator mechanisms, such as ball screw or stepper
24 motors, for example. In the preferred embodiment, motion in the vertical or upright
25 direction will be provided by a linear voice coil motor with voltage feedback.

26 To provide the ability to control the robot 20 and position it where desired
27 for the assembly operations, each motion providing device will include the
28 appropriate position feedback system for providing position information to the
29 controller or computer 22. Movement in the angular or θ direction can be provided
30 by a rotary servo motor with an encoder providing the desired feedback. As with the
31 movement in the rectangular coordinate system, the angular movement could be

1 provided with alternative devices including any other known type of rotary actuated
2 stage mechanism capable of providing the desired motion at the desired accuracy.
3 Once again, the rotary motion mechanism will provide controller or computer 22
4 with the appropriate position information.

5 Manipulator arm 38 includes as shown a load support portion 46 and an
6 upright portion 48 elongated in the upright direction, though this configuration is
7 not critical to the present invention. Portions 46 and 48 provide a support for the
8 tools and instruments used to attach the components to be assembled to each other.
9 These tools and instruments include a global vision system, an adhesive dispense
10 system, a vacuum collet, an adhesive tack system, and a local vision system, each
11 to be described in greater detail hereafter.

12 Referring now to Figures 2-4, the manipulator arm 38 will be described in
13 additional detail. Arm 38 includes a global vision imaging system (GVS) 50 that
14 includes in a preferred embodiment a charged couple device (CCD), camera, a
15 lighting system, and the appropriate lens and positioning algorithms. GVS 50 is
16 useful for globally or grossly positioning the arm 38 relative to each of the trays 16
17 and 18. The GVS 50 will also determine the position of the trays 16 and 18 relative
18 to an absolute coordinate system defined by the position feedback systems used
19 with the XY stages. A particular advantage of using the GVS 50 is that precise
20 positioning of the component trays 16 and 18 within the apparatus 10 is not
21 required. In addition, the GVS 50 will take into account any variations in the
22 manufacturing tolerances of the component trays 16 and 18. That is, even assuming
23 that the trays 16 and 18 were precisely positioned relative to the apparatus 10,
24 manufacturing tolerances in the trays 16 and 18 could result in the actual
25 components being located at differing locations. These position differences in the
26 component locations are thus accounted for by the GVS 50.

27 Also included is a local vision system (LVS) 52. As with the GVS 50, LVS
28 52 may include a CCD camera, a lens system, a lighting system, and vision
29 processing tools/algorithms used by the appropriate controller or computer 22 to aid
30 in the precision positioning of the arm 38. The CCD camera is preferably mounted
31 to the arm 38 so as to be movable in the X and Y directions. Where the GVS 50

1 was used to grossly position the arm 38 relative to the component trays and thus the
2 absolute coordinate system defined by the position feedback system, the LVS is
3 provided for locating the arm 38 relative to actual components to be assembled to
4 each other. Thus, the LVS 52 can be operated to image the components, such as a
5 flex circuit and a suspension. These images can then be used by the computer 22
6 or other controller as desired, each supplied with the appropriate vision processing
7 software, to control the movement of the robot 20 in the X, Y and θ stages. In this
8 way then, the robot 20 can be precisely positioned with respect to first one
9 component, such as a flex circuit, and then relative to a second (or third or more
10 components if multiple components are being assembled to each other) in order to
11 assemble the components to each other. Preferably, the absolute position relative
12 to the global coordinate system will not be used to precisely position the arm 38
13 relative to the components. Rather, the position of the components themselves
14 relative to each other will provide the position information used for the precision
15 alignment of the components relative to each other.

16 Figures 2-3 further illustrate a component manipulation system. The present
17 invention contemplates the use of a vacuum system to pick up and move the
18 components for assembly. The present invention utilizes a vacuum collet 54
19 mounted for movement along all four stages, that is the X, Y, Z, and θ stages. The
20 use of vacuum component manipulation systems for robotic assembly are well
21 known and will not be expounded upon here. Suffice it to say that such systems
22 utilize a precisely configured tool head that is maneuvered into position relative to
23 a component, the tool head is carefully applied to the component and a vacuum
24 applied to the tool head. In this way, the component is held to the tool head by the
25 differential air pressure between the atmosphere and the vacuum inside the tool
26 head. The tool head is then maneuvered along with the component to the next stage
27 in the assembly process. In the present invention, the vacuum collet 54 will be used
28 to first pick up a flex circuit from either tray 16 or 18, depending upon the
29 programming of the apparatus 10. The pick up of the flex circuit will be
30 accomplished by the movement of arm 38 using first the X and Y stages to position
31 the arm 38 above the flex circuit and using the Z and θ stages to lower the vacuum

1 collet shaft (not shown) and the attached collet 54 such that the collet 54 is in
2 position to apply the vacuum. The vacuum collet will then be moved to a position
3 above and relative to the suspension to which it will be bonded using the X, and/or
4 Y and/or θ stages. The LVS will then be used to position the flex circuit precisely
5 relative to the suspension using the X and/or Y and/or Z and/or θ stages. The parts
6 will then be attached or otherwise fastened to each other. Where the apparatus 10
7 is provided with the ability to identify damaged or defective parts, the vacuum
8 collet 54 may be used for additional tasks such as removing such parts from the
9 trays 16 and 18.

10 Also shown in the Figures is an adhesive dispense system 56. The adhesive
11 dispense system 56 will include at least one adhesive dispensing unit, such as unit
12 58 as shown in the Figure, mounted to the manipulator arm portion 48. Unit 58
13 includes a syringe or other adhesive reservoir 60 as well as a dispensing tip or
14 needle 62. The reservoir 60 will be connected to the tip 62 via a hose or other
15 conduit or channel 64. The unit 58 will be movable preferably in the X and Y
16 direction using the X and Y Stages, as well as in the Z direction. In the preferred
17 embodiment of the present invention, such Z movement will be accomplished with
18 a separate actuator such as a pneumatic cylinder 66. In the preferred embodiment,
19 the adhesive dispense units 58 may comprise a needle valve 67, which includes a
20 valve movable in the Z direction for dispensing of the adhesive. Alternatively, they
21 can also comprise spool valves, time-pressure valves, positive displacement valves,
22 auger valves or any other type of adhesive dispensing mechanism.

23 The present invention further includes an improved lighting system for
24 illumination of the various components to provide a more effective imaging of the
25 component parts, particularly when using LVS 52. Referring now to Figures 2-4,
26 the improved lighting system 68 will be described. The lighting system 68 includes
27 at least one and preferably a plurality of illumination sources 70. Preferably, a
28 single light source is used to provide illumination to a bifurcated optical fiber so as
29 to provide uniform, nearly equal illumination from at least two directions to reduce
30 shadowing. Sources 70 direct their light onto a diffuser 72. To provide the high
31 quality illumination needed to illuminate the trays and the components, the light

1 from the source 70 should preferably be directed at an angle of 15° , and within the
2 range of 0° to 30° with respect to the diffuser surface 74, which should be
3 substantially planar. Additionally, the light exit 76 from source 70 should be
4 disposed at a distance within the range of about 5 to about 40 mm.

5 The present invention further includes an ultraviolet or UV tack system for
6 at least partially curing the adhesive applied by adhesive dispense unit 58. The UV
7 tack system 78, which includes an ultraviolet light source, provides a "quick tack"
8 of the components to each other, here the flex circuit to the suspension, after
9 application of the adhesive and attachment of the component parts one to the other.
10 The quick tack provided by the system 78 substantially prevents the damaging loss
11 of the precision positioning achieved by the combined operation of the vision
12 systems and the manipulator arm 38, thus assuring that the relative placement of the
13 components (the flex circuit relative to the suspension, for example) does not
14 change before the adhesive is fully cured in a curing oven later in the assembly
15 process. Dependent upon a number of factors, such as but not limited to the specific
16 adhesive being used and the component geometry, the UV quick tack step may or
17 may not be required.

18 Having previously described an apparatus useful in accord with the present
19 invention, a method of assembling component parts in accord with the present
20 invention will now be described. Referring to Figure 5, then, a flow chart illustrates
21 a method 100 for assembling component parts together. Thus, as seen in the figure,
22 method 100 includes the step 102 of loading trays, such as trays 16 and 18, into the
23 apparatus 10. The trays 16 and 18 will be pre-loaded with the components,
24 indicated by the "A" and "B" in step 102, to be assembled together.

25 The use of pre-loaded trays has several advantages over the prior art
26 assembly using human operators. First and foremost is that the handling of the
27 components by human operators is eliminated. This can eliminate several possible
28 sources of component failure, including, but not limited to, damage directly caused
29 by the handling of the component by the human operator, contamination of the
30 components, and damage caused by electrostatic discharge. In a preferred
31 embodiment of the present invention, the trays would typically include the requisite

1 numbers of components such that new trays would be installed and completed trays
2 would be removed at the same time to reduce the down time on the apparatus 10.
3 The trays could be loaded by operators or automated load stations. Preferably, the
4 apparatus 10 will include apparatus for clamping or otherwise securing of the trays
5 such that the trays can not be located in the incorrect orientation or location. This
6 may be accomplished by a vacuum or mechanical clamp. The employment of the
7 trays or some other similar apparatus to "rough position" the components reduces
8 the amount of handling, the need for other tooling currently used in the manual
9 assembly of such devices, and the use of the global vision system to more precisely
10 align the parts prior to assembly.

11 Following loading of the trays, the apparatus 10 will then, if it has not
12 already done so, establish the global coordinate system (GBS) as at 104 as
13 determined by the data provided by the position feedback mechanisms of the X and
14 Y stages. Once the global coordinate has been established, it may be used to
15 precisely locate the trays relative thereto.

16 The establishment of the GBS is accomplished in the preferred embodiment
17 through the use of glass scale encoders attached to the linear servos that serve as
18 actuators for the X and Y stages. Those skilled in the art will recognize that the use
19 of such information enables the apparatus 10 to establish a coordinate system with
20 an origin defined accordingly and to provide for the movement of the manipulator
21 arm 38 to precise points (x,y) as determined relative to the origin (0,0) located
22 according to the established GBS. For example, the arm 38 could be moved to a
23 point (38, 88) which would be 38 units in the positive x direction and 88 units in the
24 positive y direction. The units of movement could be units of length or encoder
25 units or whatever unit is selected for use.

26 After the component trays have been loaded into the apparatus 10, the GVS
27 along with the arm 38 will be moved to predefined or predetermined initial
28 locations relative to the GBS. The predefined initial position is located so as to
29 position the GVS relatively near the trays 16 and 18 such that it is able to image and
30 locate a predetermined number, preferably two, of optical targets or fiducials
31 located thereon. By determining the location of the fiducials the location of the

1 trays can be determined. To determine the position of the fiducials relative to the
2 GBS, the GVS will image the fiducials and then use vision processing tools and/or
3 algorithms to precisely locate the fiducials. Thus, locating the fiducials will
4 determine the tray positions relative to the X, Y, and θ directions. Knowing the tray
5 locations in turn locates the positions of the components within the trays since the
6 locations of the components within the tray relative to the fiducials will also be
7 known. Thus, the component cavities holding components such as flex circuits and
8 suspensions, will now be located and labeled as to their respective row number and
9 column number in their respective trays, and each of these (row, column) labels will
10 have a precise X and Y (X,Y) coordinate associated with it. That is, each tray may
11 include cavities or receptacles of a predetermined configuration where the
12 components reside. Locating the trays relative to the GBS with the GVS will thus
13 locate the cavities or receptacles and, therefore, the components.

14 Once the GVS has isolated each component part as to its location relative
15 to the GBS, the parts can be bonded to each other. In summary, the adhesive will
16 be dispensed onto one part, the second part will be picked up and placed on the first
17 part, the UV quick tack will be applied to tack the parts together, and the process
18 will be repeated.

19 In greater detail, the manipulator arm 38 will be moved in the X and Y
20 directions to position the adhesive dispense unit 56 above the component, such as
21 a suspension. The z actuator 66 for the needle tip 62 will be actuated to lower the
22 needle tip to the proper height above the component for the dispensing of the
23 adhesive and the adhesive will be dispensed as indicated at 106 using the needle
24 valve 67 in a controlled volume at a controlled rate and in a controlled pattern, all
25 of which may vary according to geometry and specifications of the particular
26 components being assembled.

27 Preferably, the LVS is not used during the adhesive dispense step and the
28 adhesive is dispensed based upon the location of the cavity as determined by the
29 GVS. The LVS can be used if desired to position the needle tip 62 at the desired
30 location, but doing so will result in an increase in the cycle time, and the time to
31 complete an assembly.

1 Following the dispensing of the adhesive, the component to be bonded to
2 the first component will be picked up by the vacuum collet 54 as at 108 where it is
3 indicated that the collet picks component A. To accomplish this arm 38 will be
4 moved over to the other component tray, such as the flex circuit tray, and the
5 vacuum collet 54 will be positioned over the component to be bonded to the
6 component in the first tray. The Z stage actuator will then lower the collet 54 as
7 determined by the feedback system associated with the actuator steps with a precise,
8 predetermined force relative to the component, coming into sufficient contact with
9 the component such that upon engaging the vacuum the component will be held by
10 the differential air pressure to the collet. The Z stage actuator will be actuated again
11 and the collet and attached component will be lifted or picked up. The picking up
12 of the second component can be a "blind pick" based upon the calculated position
13 of the component to be picked up, or one of the vision systems can be used to
14 precisely position the collet in the X, Y, and θ directions relative to the component.
15 Once again, to reduce assembly cycle time it is preferred that the pick be a blind
16 pick.

17 The arm 38 then moves to position the picked component "A" over the
18 component "B" as indicated at 110. As an example of this step, the arm 38 is
19 moved so as to position the collet 54 holding the flex circuit over the suspension
20 upon which adhesive has been dispensed. While this may be the same component
21 upon which adhesive has just been dispensed, it need not necessarily be the case.
22 For example, it may be desirous to allow the adhesive to cure for a predetermined
23 period of time before the parts are bonded to each other, in which case, a second
24 component could be bonded to a first component after some period of cure time.
25 For example, processing could begin with application of adhesive to a plurality of
26 components and then the alternating process of adhesive application and part
27 bonding could be conducted, with the second component being bonded to the first
28 component having adhesive applied for the longest time.

29 After the collet 54 is moved over the component with the adhesive applied
30 to it, both components will be within the field of view, shown generally and not to
31 scale as dotted line circles FOV in Figure 6 by way of illustration only, of the LVS

1 52 and within the same depth of focus. The LVS will image the components, and
2 using fiducials or optical targets on the component parts will determine their
3 position relative to each other using vision tools and or software processing
4 algorithms. In addition, both components will be within the same depth of focus,
5 which thereby enables the LVS and GVS cameras to stay fixed relative to each
6 other. Because the LVS is fixed relative to the collet, mechanical errors arising
7 from camera movement are not introduced into the calculation of the relative
8 component positions. Once the precise relative positions are identified, the collet
9 38 will be positioned using the X, Y, and θ stages to align the first and second
10 components for bonding. This positioning may be done using a single image
11 capture, position calculation, and movement of the arm 38, or it may be repeated
12 several times to achieve the desired placement accuracy. The number of iterations
13 of imaging, calculation, and movement can be dependant on such factors as stage
14 quality, that is, movement precision, specifications required, vibration in the
15 production plant, etc. The relative component position determination can be
16 accomplished in different ways according to several known several methods;
17 generally, the relative positions will be calculated using algebra and trigonometry
18 in combination with the precise dimensions of the components, which will have
19 previously been entered into the computer on a part specific basis.

20 In some assembly procedures, the step of aligning the component parts may
21 focus on alignment of the fiducials or optical targets. In other assembly procedures,
22 computer 22 may have been programmed with the locations of alignment targets out
23 of the field of view of the LVS. In this latter situation, the alignment of those out
24 of view alignment targets will be made by calculating the relative locations of those
25 alignment targets using information concerning the parts previously programmed
26 into the computer 22.

27 Preferably, the present method utilizes a small field of view in the LVS to
28 increase the accuracy and precision of the procedure. That is, in a preferred
29 embodiment a field of view of 2 mm by 2 mm in size is utilized. Preferably, using
30 presently available optical equipment the field of view will be less than about 4 mm
31 by about 4 mm. The small field of view also enables the items of interest to be

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WHAT IS CLAIMED IS:

CLAIMS

- 1 1. A method for assembling a plurality of components to each other, said
2 method comprising:
3 determining an absolute reference system;
4 providing at least one source for a plurality of components;
5 determining the location of the at least one source relative to the absolute
6 reference system;
7 determining the locations of the components relative to the source;
8 dispensing an adhesive onto a first of the components; and
9 disposing a second of the components into an adhering position relative to
10 the first component.
2. The method of claim 1 and further including:
 determining the location of the second component relative to the first
 component.
3. The method of claim 2 and further including:
 curing the adhesive at least partially.
4. The method of claim 3 wherein said curing step includes:
 exposing the adhesive to an ultraviolet light source.
5. The method of claim 1 and further including:
 curing the adhesive at least partially.
6. The method of claim 5 wherein said curing step includes:
 exposing the adhesive to an ultraviolet light source.
7. The method of claim 1 wherein the first component is a flex circuit.
8. The method of claim 7 wherein the first component is a suspension.

9. The method of claim 1 wherein the first component is a suspension.
10. The method of claim 1 wherein the source includes optical targets and further including:
determining the location of the optical targets relative to the absolute reference system.
11. The method of claim 1 wherein said step of determining the location of the at least one source comprises:
imaging the at least one source with a first camera.
12. The method of claim 11 and further including:
disposing the source at a predetermined source location; and
disposing the first camera at a predetermined initial position for imaging the at least one source.
13. The method of claim 1 wherein the source comprises at least one tray holding the components.
14. The method of claim 1
determining the relative positions of the two components to be assembled to each other, said determining step including imaging the two components simultaneously with a camera.
- 1 15. The method of claim 14 wherein the source includes optical targets and
2 further including:
3 determining the location of the optical targets relative to the absolute
4 reference system, said step of determining the location of the optical
5 targets including imaging the at least one source with a camera.
16. The method of claim 15 and further including:

curing the adhesive at least partially.

17. The method of claim 16 wherein said curing step includes:
exposing the adhesive to an ultraviolet light source.

- 1 18. The method of claim 15 wherein said step of disposing a second of the
2 components into an adhering position relative to the first component comprises:
3 determining a preferred relative position of the second component relative
4 to the first component;
5 picking up the second component and moving it into an initial position
6 relative to the first component;
7 calculating the relative positions of the first and second components based
8 upon the step of imaging the components; and
9 moving the second component to a new position closer to the preferred
10 relative position.

19. The method of claim 18 and further including:
curing the adhesive at least partially.

20. The method of claim 19 wherein said curing step includes:
exposing the adhesive to an ultraviolet light source.

21. The method of claim 14 wherein the two components are aligned for
attachment calculating the relative positions of alignment targets on the components
that are out of the field of view of the cameras.

- 1 22. The method of claim 21 wherein the source includes optical targets and
2 further including:
3 determining the location of the optical targets relative to the absolute
4 reference system, said step of determining the location of the optical
5 targets including imaging the at least one source with a camera.

1 28. The method of claim 27 wherein said step of disposing a second of the
2 components into an adhering position relative to the first component
3 comprises:
4 determining a preferred relative position of the second component relative
5 to the first component;
6 picking up the second component and moving it into an initial position
7 relative to the first component;
8 calculating the relative positions of the first and second components based
9 upon the step of imaging the components; and
10 moving the second component to a new position closer to the preferred
11 relative position such that said alignment targets are properly
12 aligned for attachment of the components to each other.

29. The method of claim 28 wherein said field of view is less than about 4 mm
by 4 mm.

1 30. An apparatus for assembling at least a first component to a second
2 component, said apparatus comprising:
3 a robotic assembly apparatus including a manipulator arm movable in xyz
4 and θ directions;
5 a global vision system comprising a camera, said global vision system being
6 provided for locating the first component relative to a global
7 reference system;
8 a vacuum collet attached to said manipulator arm for manipulating at least
9 one of the components and placing it in an attachment position
10 relative to the other component wherein the components are
11 disposed substantially one above the other;
12 an adhesive dispense system attached to said manipulator arm for
13 dispensing adhesive onto at least a selected one of said components;
14 and

15 a local vision system attached to said manipulator arm, said local vision
16 system being provided for imaging both components when said
17 components are in said attachment position.

1 31. The apparatus of claim 30 wherein said local vision system includes a local
2 vision lighting system, said local vision lighting system comprising:
3 a diffuser plate; and
4 a pair of light sources directed at said diffuser plate.

32. The apparatus of claim 31 wherein said light sources are directed at said
diffuser plate from substantially opposite directions.

33. The apparatus of claim 32 wherein said diffuser plate has a substantially
planar surface and said light sources direct light at said diffuser surface at an angle
in the range of about 0° to about 30° with respect to said diffuser surface.

34. The apparatus of claim 33 wherein said light sources direct light at said
diffuser surface at an angle of about 15° with respect to said diffuser surface.

35. The apparatus of claim 33 wherein said light sources are disposed at a
distance from said diffuser surface within a range of about 5 to about 40 mm.

36. The apparatus of claim 31 wherein said diffuser plate has a substantially
planar surface and said light sources direct light at said diffuser surface at an angle
in the range of about 0° to about 30° with respect to said diffuser surface.

37. The apparatus of claim 36 wherein said light sources direct light at said
diffuser surface at an angle of about 15° with respect to said diffuser surface.

38. The apparatus of claim 36 wherein said light sources are disposed at a
distance from said diffuser surface within a range of about 5 to about 40 mm.

39. The apparatus of claim 30 and further including means for at least partially curing dispensed adhesive.

40. The apparatus of claim 39 wherein said means for at least partially curing comprises an ultraviolet light source.

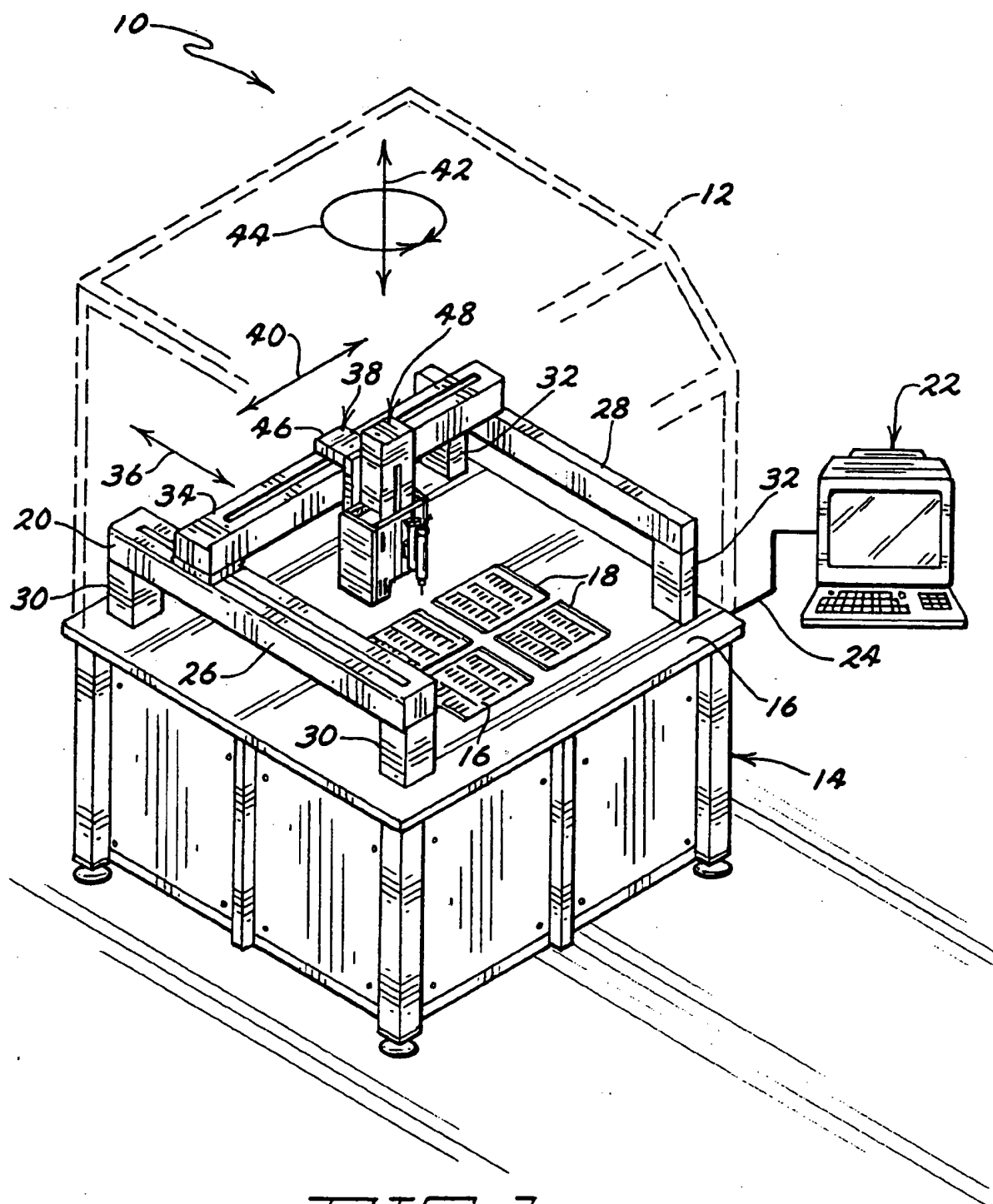
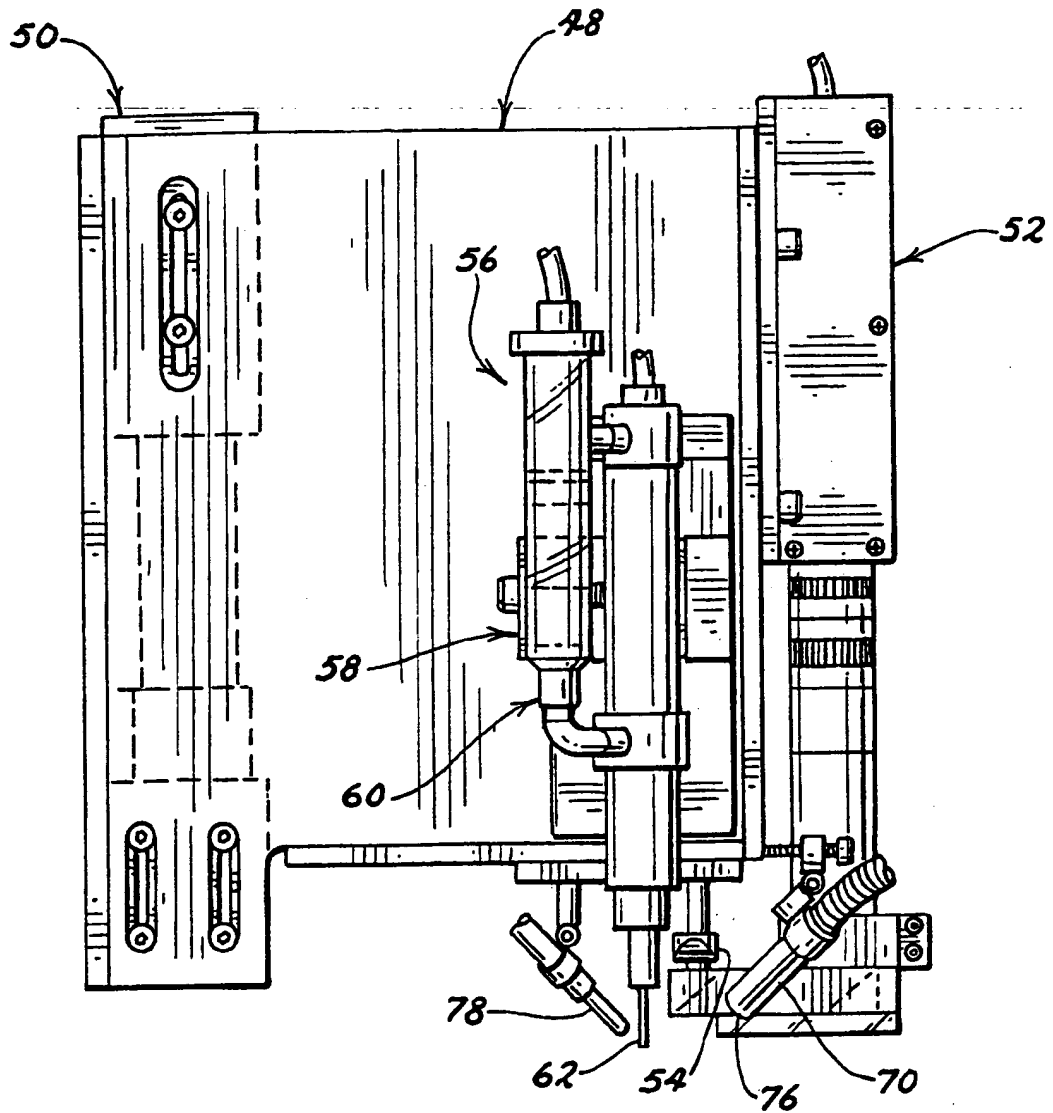


FIG. 1

*FIG. 2*

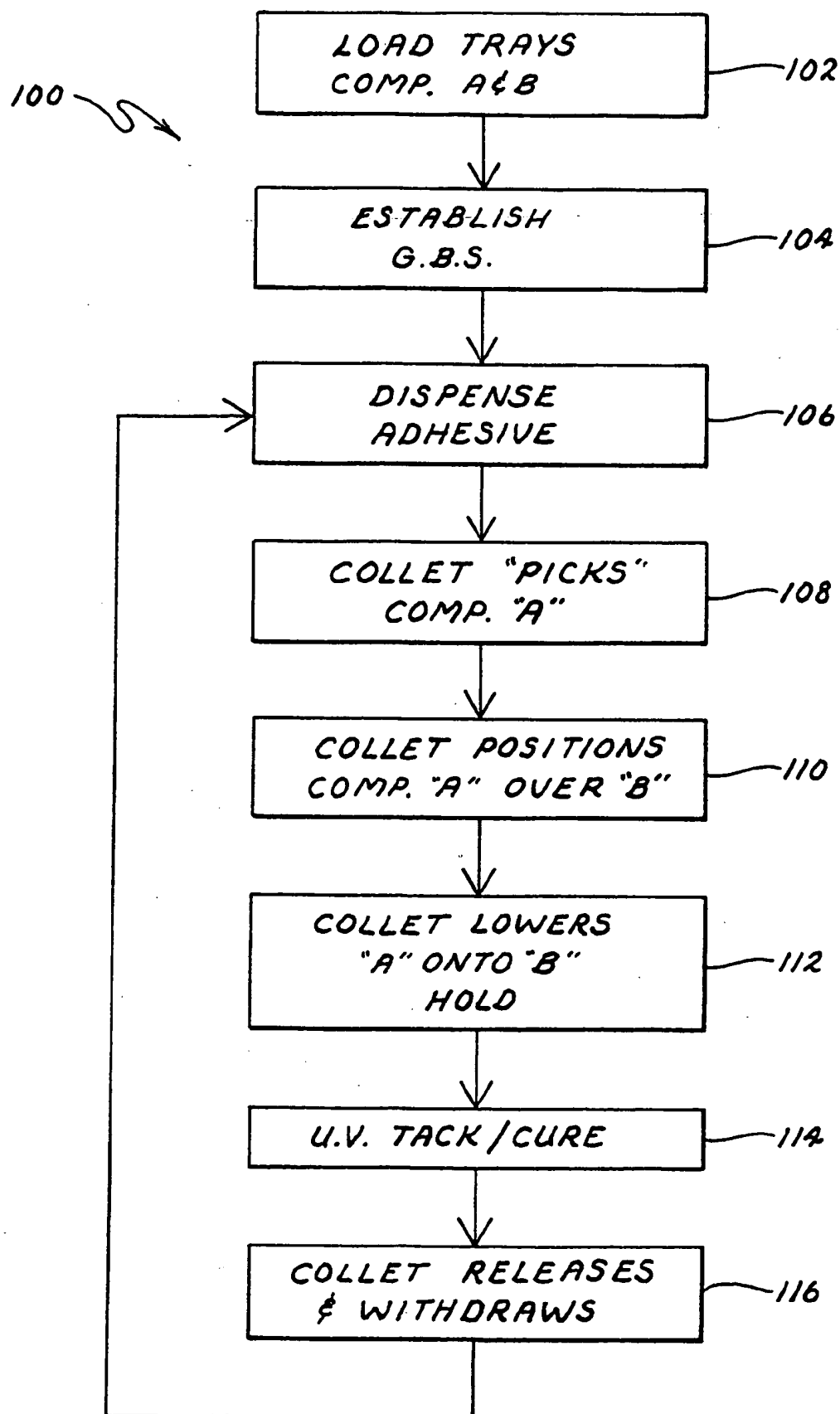


FIG. 5